U.S. Department of Agriculture Agricultural Research Service
July/Aug 1983

Agricultural Research

Managing Our Water Resource

Nearly 4.8 billion acre-feet of water fall on the 48 contiguous States each year. This is enough water to fill more than 25 quadrillion 8-oz glasses—125 million glasses for every man, woman, and child—and yet if you have no glass or any other means of collecting this water, you will die of thirst.

Such is the problem that has confronted the agricultural community since agriculture began. The fate of civilization is linked to its resolution. Like all natural resources, water must be exploited in order for people to use and benefit from it, and like all natural resources that are finite in supply, this exploitation must be managed with wisdom and care.

To provide the necessary knowledge for wise and careful water management for agriculture, research is being conducted by ARS scientists, often in cooperation with scientists from other Federal agencies, State universities and experiment stations, and private industry. Under the direction of ARS Administrator Terry B. Kinney, Jr., research programs at 38 locations nationwide, involving hundreds of scientists and support staff, encompass all aspects of water use in agriculture, ranging from cropping systems that depend only on rainfall, to systems that rely primarily on water diverted from nearby rivers.

Agriculture is by far the largest single consumer of water in this country. Of the precipitation falling annually on the 48 States, about 70 percent evaporates from the area on which it falls. The bulk of this evaporation occurs on agricultural, forest, and rangelands in the form of evapotranspiration, which includes both evaporation from the soil surface and transpiration from plants. The rest of the precipitation—some 30 percent—accumulates in ground and surface storage; flows into water bodies; is consumed by people in one fashion or another outside of direct agricultural purposes; or is evaporated from reservoirs.

Agriculture's water consumption takes place under one of three cropping conditions: dryland, limited irrigation, or full irrigation. Each has its own management problems and each has possibilities for conservation and increased water-use efficiency. The one common factor is that water remains the most limiting natural resource affecting crop production. Water-use efficiency—which is the marketable crop produced per unit of water consumed in evapotranspiration—can be used to evaluate the effectiveness of new management practices and the performance of new crop varieties.

Under dryland conditions, research has shown that water-use efficiency can be improved by increasing the amount of precipitation stored in soil during a fallow period between crops. Further research has demonstrated that the best way to increase this soil water storage is to maintain standing crop residue or straw on the soil surface through the use of conservation tillage, a management approach where the soil is either tilled without covering the residue or left undisturbed entirely.

Like dryland farming systems, limited irrigation systems aim at making the maximum use of cost-free precipitation but employ some irrigation as a backup when precipitation levels fall short of need. Researchers are currently evaluating a system in which only the upper half of a field is fully irrigated during a normal year, the next fourth receives limited irrigation, and the remaining fourth is treated as dryland except for runoff from the upper three quarters.

By producing more crop residues than would otherwise be possible, thus significantly increasing the amount of water stored in the soil during fallow, the limited irrigation system boosts water-use efficiency and grain production on the dryland portion of the field.

Full irrigation offers the most opportunities for water conservation management, since crops under this system rely primarily on water drawn and distributed—within certain physical and legal limitations, of course—at a grower's discretion. However, to put these opportunities into perspective, the volume of water involved must be understood.

Withdrawal of water from surface and groundwater supplies represents an equivalent of only about 12 percent of the mean annual streamflow in this country. Irrigation consumption is less than 3 percent of the total evaporation from the 48 contiguous States. The amount of water consumed by dryland agriculture is about 10 times the irrigation consumption.

Another misconception needing clarification is the idea that irrigated agriculture wastes much of the water it uses. Water diverted for irrigation is either consumed through evapotranspiration, stored in a nonrecoverable stratum of the earth, or returned to the original or some other usable source. This return flow is frequently ignored in water discussions, leading to false conclusions of wastefulness.

When return flow is taken into consideration, researchers have an accurate and standardized means of measuring and comparing the true effectiveness and efficiency of irrigation systems, including conveyance and on-farm distribution. Efforts can then be made to assure maximum delivery of water to users, reduce or eliminate waste along canals and on farms, and reduce energy costs. For individual users, this can translate into higher yields and a better quality product with less labor.

There are other possibilities for better using the water available to us, including snow management, the reuse of waste effluents, and perhaps one day even the manipulation of weather and precipitation itself, though prospects for this last possibility are at the moment remote. When all is said and done, however, water is a finite resource. Competition for this most precious of resources will undoubtedly intensify and agriculture's share can expect to be diminished. New technology will be needed to offset any such reduction while maintaining or—even more likely—increasing current crop production levels.

Lynn Yarris
Oakland, Calif.

Contents

Agricultural Research
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Cover: At the Southern Plains Cotton Research Laboratory in Lubbocvk, Tex., field studies of plant root systems and plant-atmosphere interactions suggest that certain strains of wild cotton from Mexico have the genetic potential to increase drought resistance in America's commercial cultivars. Article begins on p. 4 (0882X912-29A)

Correction: A May 1983 article in *Agricultural Research* incorrectly stated that phosphorus fertilizers should not be used on plants growing in zinc-deficient soils. Only zinc-deficient laboratory plants exposed to unusually high phosphorus levels in nutrient culture are known to suffer phosphorus toxicity. The field application of phosphorus fertilizers at recommended rates is therefore of no harm to crops. We regret this error.

Exotic Cotton Tolerates Semiaridity

Biological technician Wolfgang Oesterreich (left) and Texas Tech University student assistant Jeff Russell lower a scope into the ground through a plexiglass tube to view the roots of wild Mexican cotton plants. (0882X912-8A)

Top right: Images of cotton roots from the underground scope are recorded by a video camera and played back on a monitor, where they are studied for extension, depth, and density. (0882X916-6)

Wild cotton plants from Mexico may be a source of genes that could provide drought-stress tolerance to commercial cotton cultivars in the United States.

According to Bobby L. McMichael, plant physiologist at the Southern Plains Cotton Research Laboratory, Lubbock, Tex., some of the exotic cotton strains have more water-carrying vessels (vascular bundles) in their roots than do U.S. commercial cultivars.

"In our commercial cottons," McMichael says, "vascular bundles are arranged in groups of four. In some of the exotic cotton strains, however, we found vascular bundles arranged in groups of five and even six. Furthermore, the lateral root system is more developed in some of the exotic strains than in the commercial cultivars."

Since the different type of root system is a genetic trait, plant breeders should be able to breed it into commercial cotton sometime in the future. Cotton grown in semiarid parts of the country might then need much less irrigation water to produce a satisfactory lint yield.

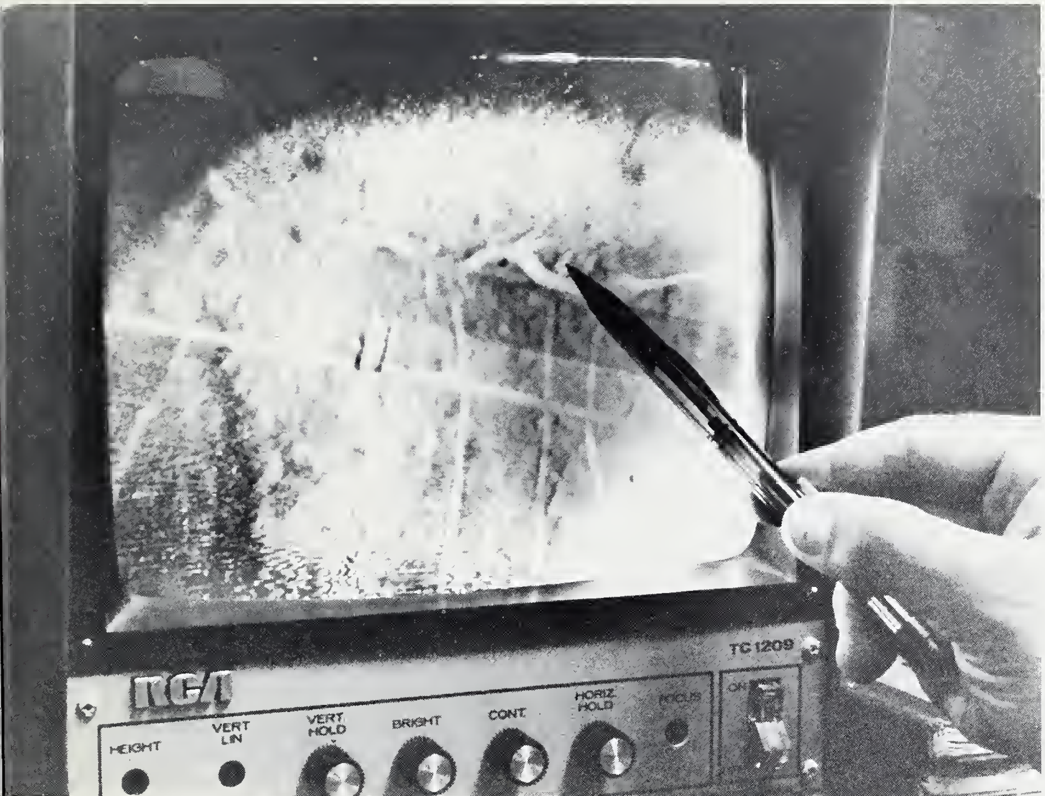
The tendency to greater drought tolerance was first noted by geneticist and laboratory director Jerry E. Quisenberry. This led McMichael and colleagues J. J. Burke, ARS plant physiologist, and Jerry Berlin, Texas Tech University biologist, to investigate the exotic plants and discover the additional vascular bundles and more vigorous lateral root systems.

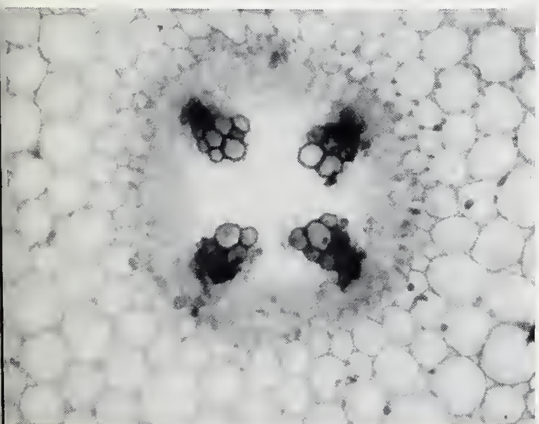
"We think it very likely that the increase in the xylem (water-carrying tissues) and the greater development of the lateral root systems of some exotic cotton strains may help to account for their observed drought tolerance," says McMichael. "When you have more pipes, you can move more water."

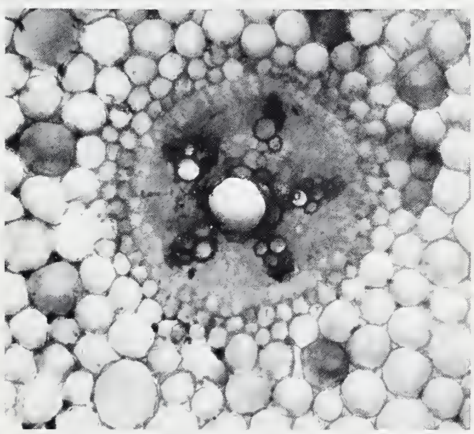
McMichael and his colleagues are continuing research to confirm the connection between the different root systems and their observed drought-stress tolerance.

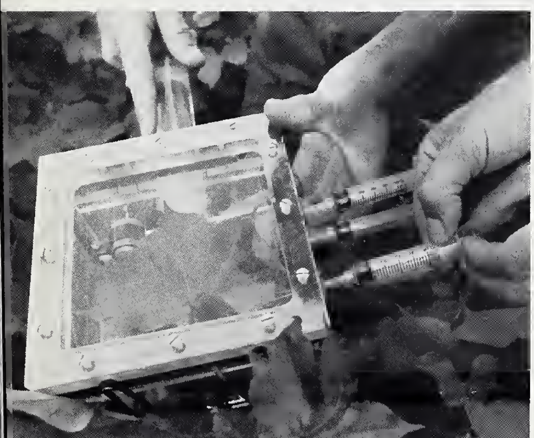
Bobby L. McMichael is located at the Southern Plains Cotton Research Laboratory, Texas A&M University, Rt. 3, Lubbock, Tex. 79401.—(By Bennett Carriere, New Orleans, La.) ■

Hydrologists Sharpen Their REPHLEXes









Above left and right: The cross section of the primary root of a commercial U.S. cotton variety (left) shows only four bundles of water-carrying vessels compared to the five bundles in the root of a wild Mexican strain (right). The latter's increased water-carrying capacity may account for its greater drought resistance. (PN-7058, PN-7057)

Left: Samples of carbon dioxide levels inside a gas-tight 'leaf respiration chamber' are gathered for investigating the relationship between plant metabolism and the root efficiency of drought-resistant Mexican cotton. (0882X912-34A)

Anyone working on a project related to the Nation's water supplies now can have instant access to 50 years of hydrologic data.

All that's required is a quick REPHLEX. . . or **RE**trieval **P**rocedures for **H**ydroLogic Data from ARS **EX**perimental Watersheds.

REPHLEX is a new computer system for gaining direct telephone access to the ARS hydrologic data bank stored in the U.S. Department of Agriculture's Washington Computer Center (WCC) in the District of Columbia. There is also a "REPHLEX User's Guide" that has recently been published by the ARS Water Data Laboratory at Beltsville, Md.

According to computer specialists Jane Thurman and Ralph Roberts, no formal computer training is necessary to use the REPHLEX system. However, nongovernment users must request to use REPHLEX through a USDA agency.

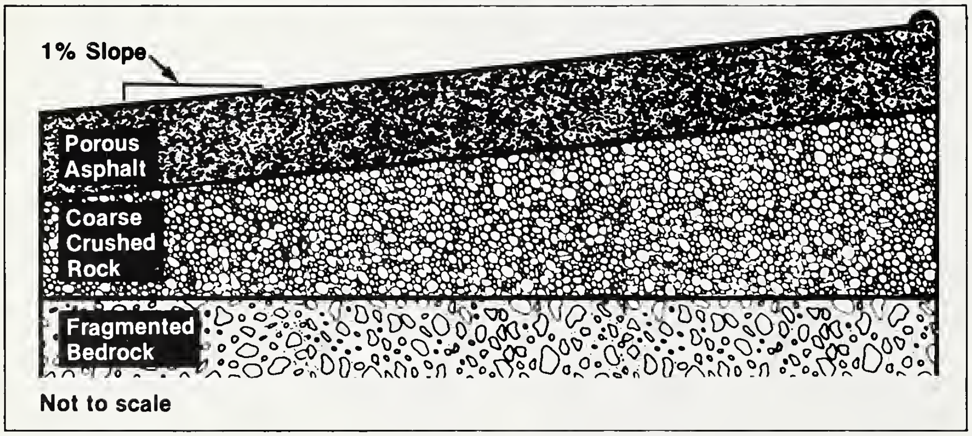
The data bank accessible by REPHLEX primarily contains precipitation and runoff records from approximately 300 watersheds around the United States. Also available (in published form) is information from comprehensive studies of over 500 "typical" watersheds, including most of the 300 studies for which data are electronically stored.

"Water, or the lack of it in some cases, has become a popular issue. And, with increased research in computerized, mathematical modeling to predict floods, certain types of water pollution, etc., the REPHLEX system gets appropriate data to users in a timely fashion," explains J. B. Burford, chief of the Water Data Laboratory, which is responsible for programming the ARS hydrologic data bank.

For many watersheds, the data bank also includes information on land use, vegetation, and cover conditions as well as soils, topography, geology, and climatological data. Most of this information is also available in published form.

To obtain a copy of the "REPHLEX User's Guide," contact the ARS Water Data Laboratory, Rm. 236, Bldg. 007, Beltsville Agricultural Research Center, Beltsville, Md. 20705, or call (301) 344-3550.—(*By Stephen Berberich, Beltsville, Md.*) ■

Designing Pavement to Capture Runoff



Porous asphalt is laid using conventional machinery and methodology. (PN-7059)

A cross-section showing the three layers of a full-section porous asphalt roadway. (PN-7061)

A new method of using porous asphalt can help return stormwater runoff to groundwater supplies for cities as well as agricultural areas, while eliminating puddles on roadways, keeping tires from skidding, and minimizing road glare.

The new method is called full-section porous asphalt, indicating that material is applied directly over a gravel bed, instead of over or under regular asphalt, as it has been up to now.

Because its high-friction surface reduces skidding in rain and snow, porous asphalt has been used as a top layer over concrete on airport runways in Europe and the United States, and on streets in several U.S. cities since the 1960's. When used as a base layer under regular asphalt, porous asphalt helps prevent cracking of the pavement by providing rapid water drainage.

Porous asphalt is manufactured by the same process as regular asphalt, but only larger sizes of gravel—between 1/10 to 1/2 inch in diameter—are used. The result is a water-permeable lattice.

Full-section porous asphalt diverts storm runoff through the asphalt surface into the ground, according to geologist James B. Urban, who led the research team at ARS's Northeastern Watershed Research Center.

To build full-section porous asphalt, the material is layered over a gravel bed. The permeability of the rock under the roadway is tested to determine the proper thickness of gravel to use. Rainwater can drain through the asphalt surface and collect in the gravel bed until it percolates into the ground.

Urban and ARS hydrologist William J. Gburek tested full-section porous asphalt for 5 years at ARS's Storm Water Detention and Groundwater Recharge facility near Willow Grove, Pa. The Pennsylvania Department of Transportation, Materials Testing Division, cooperated in the design of the test facility and specifications for the asphalt.

The scientists recorded the infiltration of stormwater under grass, full-section porous asphalt, and regular asphalt. "Almost no water seeped through the conventional asphalt; most of the water was lost through runoff. Grass and full-section porous asphalt were almost equally effective in reducing runoff during the growing season," Gburek says.

About 75 percent of the rainwater seeped through the full-section porous

Pollutants from Coal May Work as Fertilizer

At a test plot near Willow Grove, Pa., measurements are taken to determine groundwater recharging under porous asphalt and water percolation through the material. (PN-7060)

asphalt into the groundwater supplies, Urban says, contrasted with approximately 20 percent under a grassy plot and close to 0 percent under regular asphalt.

"Full-section porous asphalt is much more effective than grass for recharging groundwater," Urban says. During the growing season, grass and other plants use the water in the upper soil layers, preventing it from reaching the water table.

The water table under the full-section porous asphalt rose about 2 to 5 feet for each inch of rainfall at the test site in Pennsylvania. The groundwater level started to rise 2 hours after a storm began, and began to drop about 6 hours after the storm.

Full-section porous asphalt is strong enough to support light-duty traffic, according to Urban. This new method of using porous asphalt can be used for parking lots and light-duty roads, he says.

James B. Urban and William J. Gburek are located at the Northeastern Watershed Research Laboratory, 111 Research Bldg. A, University Park, Pa. 16802—(By Ellen Mika, Beltsville, Md.) ■

An emerging technology that strips burning coal of pollutants may soon be providing agriculture with an important new source of fertilizer.

In "fluidized bed combustion" (FBC), crushed coal is burned in a slurry of limestone or dolomite (a calcium-rich mineral) that reduces sulfur and nitrogen emissions by more than 90 percent. The pollutants are trapped as a granular residue surprisingly rich in plant nutrients.

Taking the residual nutrients from furnace to farm is the goal of a 5-year joint project of ARS and the U.S. Department of Energy. ARS laboratories throughout the Eastern United States are evaluating FBC residue's possible agricultural uses.

The task is an important one. As many American utilities and industries switch from oil and gas to coal, FBC is one of the few technologies able to stem the resultant rise in sulfur and nitrogen oxides. These pollutants are a major source of acid rain and other forms of acidic deposition.

The fluidized bed combustion process, however, generates tons of granular waste. Unless uses are found, disposing of the residue becomes a pollution problem in itself.

Fortunately, FBC residue is rich in calcium, magnesium, and sulfur—elements required for plant growth. Orus L. Bennett, director of the Appalachian Soil and Water Conservation Research Laboratory in Beckley, W. Va., views the future agricultural use of FBC residue as a "tremendous opportunity" not to be missed.

"FBC residue will be a major source of liming material if fluidized bed combustion is widely accepted by the power industry, as is expected," Bennett says. "The Tennessee Valley Authority is operating a 20-MW pilot atmospheric fluidized bed combustion power plant in Kentucky and plans to build a full-size plant in the near future."

The agricultural opportunity presented by this emerging technology, however, has required careful analysis by ARS scientists. The mere presence of nutrients in the residue does not guarantee their uptake by plants. Their chemical forms or the presence of other, extraneous compounds could render some of the nutrients unavailable to crops.

Moreover, FBC can and often does contain heavy metals that can be, in sufficient amounts, toxic to plants, animals, and humans. But as noted previously, the presence of compounds in the soil does not guarantee their absorption into the food chain. Bennett and ARS colleagues in New Jersey, Pennsylvania, Maryland, and eight other Eastern States are conducting experiments in the greenhouse, growth chamber, and field to be sure that such compounds do not reach harmful concentrations in crops fertilized with FBC residue.

Plant growth studies have been encouraging. Tomatoes, lettuce, radishes, and other vegetables which tend to accumulate heavy metals were fertilized with FBC residue. After harvesting the crops, ARS researchers could find no significant increases in heavy metals. Instead, test plants responded favorably to the treatment. In some cases their content of calcium and sulfur, two plant nutrients also important to humans, actually increased significantly.

The scientists have also obtained promising results with pecan seedlings at Byron, Ga., and elsewhere with apples and peaches, grasses, legumes, small grains, buckwheat, and blueberries. Corn, soybean, and oat trials at Morgantown, W. Va., showed significant increases in sodium and copper nutrient levels in corn and a significantly lower than usual level of toxic cadmium in soybeans.

Cadmium concentrations in oats, however, rose slightly. If consistent year to year, such increases could limit the use of FBC residue, Bennet says.

The researchers are now conducting animal nutrition studies and other tests. Bennett and his colleagues are optimistic that FBC residue will have a place on the farm as fluidized bed combustion becomes a leading energy technology in the next several decades.

Orus L. Bennett is located at the Appalachian Soil and Water Conservation Research Laboratory, P.O. Box 867, Beckley, W. Va. 25801.—(By Andrew Walker, Beltsville, Md.) ■

Broadening Cablegation's Applications

Cooperating farmer Cal LaBeau (right) and Soil Conservation Service engineer Clarence Prestwick inspect the combined cablegation and bordered strip irrigation system on LaBeau's farm near Roosevelt, Utah. (0783X901-12)

The development of new technology can sometimes pump renewed interest into old technology.

Such is the case with cablegation, the new, ARS-developed, energy-saving, automatic surface irrigation system, and the older idea of bordered strip irrigation.

Cablegation systems can make bordered strip irrigation a much more practical and attractive alternative to furrow irrigation for highly permeable soils, recent ARS studies have shown.

When soils with high infiltration rates are irrigated, water must be moved down the fields quickly. Otherwise, the lower ends of the fields receive little water, while the upper ends become so saturated that excess water percolates below plant root zones, leaching away nitrates and often picking up harmful salts which ultimately get deposited into rivers.

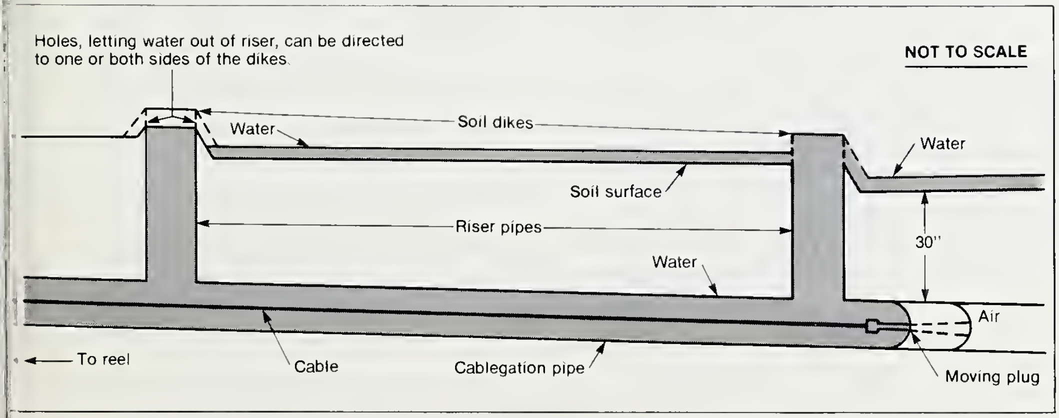
Research has shown that bordered strips are excellent for moving water quickly down a field. Instead of being dispersed into many furrows, water is allowed to spread out in strips ranging from 20 to 100 feet wide. The strips are leveled and bordered on each side with 6-inch-high earth dikes.

Though generally recognized as the best method of surface irrigation for permeable soils, bordered strip irrigation has not been as widely accepted by growers as it should have been. A major deterrent has been that users must attend their fields frequently to divert water from strip to strip: not too practical from a grower's standpoint, particularly at night, or when there is other work to be done.

Cablegation, however, once set in operation, requires no aid from growers to redirect water from one strip to the next. Developed by W. Doral Kemper, director of ARS' Snake River Conservation Research Center, Kimberly, Idaho, along with other researchers at the Center (see *Agricultural Research*, June 1981, p. 7), cablegation uses gravity to deliver water to furrows automatically and sequentially for any desired length of time. The system requires little labor to operate and provides water applications almost as uniform as those of sprinkler systems.

Basically, the cablegation system is a single, carefully graded pipeline with holes drilled into one side. Inside the pipe is a plug attached to a feeder reel by a cable. The plug acts as a brake when water passes through the pipe,

LaBeau (left) and Prestwick measure the flow rate from a riser on the cablegation system installed on LaBeau's farm. The system was designed by ARS and constructed with technical assistance from SCS. (0783X904-1)



Cablegation on bordered strips allows the pipe and cable system to be installed underground, with large risers bringing water to the soil surface. (PN-7030)

backing the water up and forcing it out through the holes. Controlling the rate at which the plug moves down the pipe controls the irrigation rate.

Once put into place, cablegation is relatively inexpensive to operate. The major cost of the system is the initial purchase and installation of a single, carefully graded polyvinyl chloride (PVC) plastic pipeline.

Although originally designed for furrow irrigation, the cablegation system can be inexpensively adapted for use on bordered-strip fields simply by drilling larger holes into a standard cablegation pipe. Such holes can be covered should the system again be used on furrows.

If all irrigations will be on bordered strips, the line can be buried underground with large risers bringing water to the soil surface for each strip. Proper design of the riser openings and elevations can direct all of the water to one strip at a time, with reduced flow during the last half of the irrigation cycle on each strip.

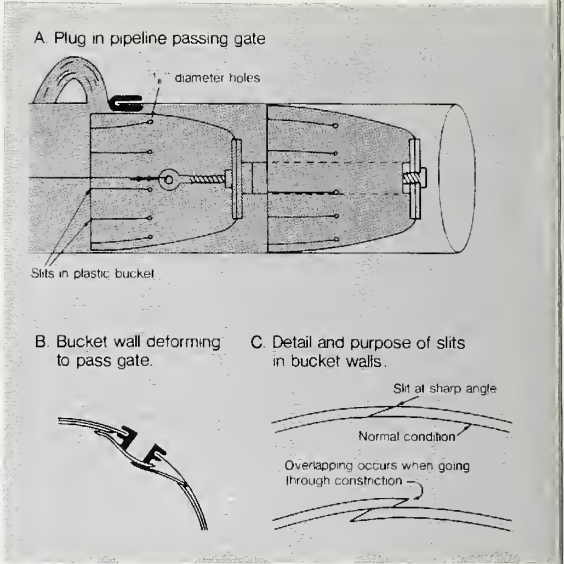
Cablegation in Gated Pipe Systems

A large portion of today's surface irrigation systems use piping with adjustable gates to deliver and distribute water to furrows. These gates protrude about 1/2 inch into the pipe, and previous efforts to use cablegation with them were unsuccessful because the plug would either get hung up on the gates or else push the gates into a more open or closed position.

Kemper and ARS technician Jim Chapman have been able to overcome the problem by modifying the plug.

Explains Kemper, "The previous plug used two flexible polyethylene bowls with open sides facing upstream. The modified plug uses two rubberized plastic bowls made even more flexible by cutting about a dozen slits from the top about halfway to the bottom of each bowl. These slits are made at an angle to the wall so that the intermediate strips of plastic can slide over each other when a constriction or protruding gate is encountered.

ARS Snake River Conservation Center director W. Doral Kemper, who developed cablegation, holds a modified plug that makes it possible to use cablegation in an already existing gated pipe irrigation system. (0782X780-36)



Slits in the rubber bowls of the newly designed plug enable sections of each bowl to overlap, compressing the bowl so that it can squeeze past the gates in gated pipe irrigation systems. The noncompressed plug keeps water from escaping into the pipe ahead. (PN-7044)

"As one of the plug's two bowls passes a protruding gate, that bowl deforms, enabling it to clear the gate. Water can pass the deformed bowl, but is still stopped because the other bowl is always in a smooth, round section of the pipe."

To prevent the slits in the bowls from progressing (much like a crack in a windshield gets larger if left unattended), holes about 1/8 inch in diameter are drilled at the end of each slit.

A cooperating grower tested the new plug in his conventional PVC gated pipe during the 1982 irrigation season. He concluded, "It provided more uniform irrigation, used no gas or electricity, and saved me time that I needed for other farm operations."

Kemper and his colleagues are continuing to study cablegation and bordered strip irrigation in cooperation with the Soil Conservation Service and growers.

W. Doral Kemper is located at the Snake River Conservation Research Center, Rt. 1, Box 186, Kimberly, Idaho 83341.—(By Lynn Yarris, Oakland, Calif.) ■

A Future for Lean

Selecting breeding swine for leanness generally has slowed if not stopped in the last 6 years, but possibilities for further progress are good.

This view is expressed by ARS animal geneticist Gordon E. Dickerson, a member of the staff of the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr. Dickerson conducts studies at Lincoln, Nebr., on the effects of genetic changes in swine on alternative management, marketing, and breeding systems.

The scientist suggests that future price incentives for producing lean pork eventually will lead to a decrease in the average percentage of fat in hog carcasses from the present plateau of about 30 percent. Chicken and turkey carcasses are in the range of 10 to 15 percent.

It costs money to produce fat that consumers don't want.

A computer model of pork production that Dickerson and his colleagues at the University of Nebraska have developed shows how genetic changes affect input costs and the total retail value of meat produced. From this model, post-doctoral geneticist Gary L. Bennett, graduate assistant Michael W. Tess, and Dickerson observed that the most important swine breeding objective could become leanness.

There's one kicker. Breeding for leanness is not likely to become more important unless prices that farmers receive will be based on retail value of the meat rather than on live weight.

"If you're not being paid for lean value, little is gained by increasing leanness," says Dickerson. "One reason is that faster lean gain requires more protein feed supplement and increases cost of the hog's diet. Also, leaner sows will have higher feed requirements."

Will there be a trend toward realistic premiums for leanness? The breeder has to try to look ahead. One way or another, Dickerson says, it seems that markets must move toward paying for the real meat value in market hogs.

One means of achieving more realistic prices could be the widespread use of some trustworthy system of animal identification and carcass grading on the basis of lean yield, Dickerson says. However, until lean hogs become more prevalent or until yield grading is generally practiced, many packers may be reluctant to discriminate on the basis of yield: producers might not bring enough hogs in to keep individual packers' slaughter lines operating steadily at full tilt.

Breeders' concern that lean pigs might be more susceptible to pork stress syndrome (PSS) is another impediment to breeding for leanness. Pork from a PSS-affected animal is soft, and some hogs die from PSS on their way to market. But Dickerson says research at Iowa State University and in Europe is pointing to ways that this hindrance may be overcome.

PSS may result primarily from the expression of one major gene that can be identified by testing pigs with the anesthetic gas halothane. Young pigs that have received the PSS gene from both parents become rigid under halothane testing. Further research on the halothane test will be needed to establish its usefulness as a selection tool to reduce the frequency of PSS in breeding stock, Dickerson says.

Bulging or double muscling has also been associated with PSS. But it's not necessary to have bulging muscles to have a lean animal, the researcher says. Breeders who have selected for leanness by visual appraisal of muscling prominence may have tended to select animals with PSS. Testing for leanness with backfat probes or ultrasonic techniques can help breeders identify lean hogs that don't necessarily have bulging muscles, Dickerson says.

If improvements in selection for leanness and payment of adequate premiums for lean come about, the consumer will benefit. For every pound of lean pork the public consumed, there would be less overhead investment in feed and nonfeed costs on the farm.

The researchers' production system model was used to indicate how a given reduction in percentage of carcass fat would change the cost of producing pork under various sets of conditions. Information in the computer model comes from actual research data on genetics, energy metabolism, physiology, meats, management, and marketing.

According to the model, a 20-percent decrease in body fat content along with a 20-percent increase in growth rate in hogs marketed at a given age should reduce total costs per pound of carcass lean by about 14 percent. That's about a 5-percent reduction in total costs per pound of live weight.

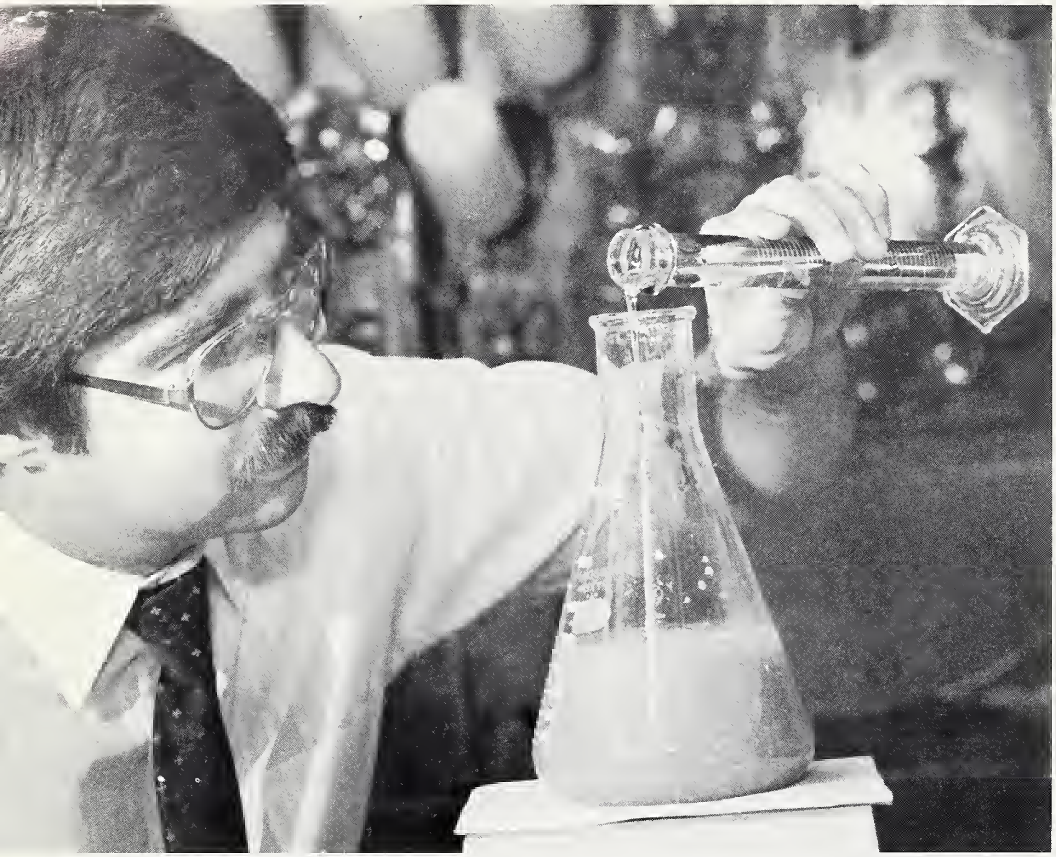
Assuming that the producer is getting paid for hams and pork chops instead of live weight, it's more important to make the decrease in fatness than it is to increase the growth rate, especially if the hogs are being marketed at a fixed weight, says Dickerson.

Moreover, it is much easier genetically to breed for degree of fatness than to breed for a higher growth rate. However, without a premium for leanness, less fat actually increases costs, and faster gains are beneficial only if pigs are marketed at the heavier weights for the same age.

"This research modeling has toned down our excitement about growth rate, especially when the growth rate is associated with heavier sows with higher overhead costs," says Dickerson. "It has highlighted the potential importance of reducing fat and increasing litter size."

Gordon E. Dickerson is located in Rm. 255, Marvel Baker Hall, University of Nebraska, Lincoln, Nebr. 68583.—(By Ben Hardin, Peoria, Ill.) ■

Peroxide Opens Plant Energy Package



Biochemist J. Michael Gould adds an alkaline solution of hydrogen peroxide to ground straw. The peroxide makes the lignin and the components of plant cellulose in the straw available for use in a variety of ways (0783X882-23)

Hydrogen peroxide can loosen one of the tightest energy packages a plant can wrap.

It might loosen one of the tightest natural restrictions on increasing feed and food production without increasing crop production.

Cellulose wrapped in lignin in plant stems and other residues is not easily digested to its energy-yielding unit, glucose sugar (see *Agricultural Research*, May 1980, p. 10, and Nov. 1982, p. 4).

But peroxide, it has been discovered, dissolves more than half the lignin and opens the cellulose in wheat straw. This makes the components of cellulose available for digestion by enzymes in cattle and microorganisms, and for conversion to chemical raw materials. The peroxide treatment frees 93 percent of the straw, including the cellulose, most of the lignin, and hemicellulose, another sugar source.

A Northern Regional Research Center (NRRC) study demonstrates the possibility of replacing feed grains with weeds and unused parts of crop plants as the energy source for ruminants. A first step toward realizing the potential—animal feeding tests—has started in cooperation with the University of Illinois. Feeding cattle plant parts that humans cannot digest would save the grain for people and provide protein in meat and milk.

Biochemist J. Michael Gould uses a moderately alkaline solution (pH 11.5) of hydrogen peroxide, a common antiseptic and bleach, to treat plant parts—straw, corn stalks, husks and cobs, stems of soybeans and of foxtail (a weed grass), kenaf stalks, and oak wood shavings—for 12 to 18 hours. "Chemical energy from the peroxide makes the reaction go at room temperature," he says. It saves the cost of the fuel for heating.

At about the alkalinity of strong soap, the peroxide (HOOH) breaks down, Gould says. Some of the products oxidize lignin, exposing the cellulose. The oxidized lignin fragments are not toxic to animals or microorganisms.

"Changes in composition are accomplished by dramatic changes in physical properties," Gould says. "During the straw treatment, for instance, chopped straw disintegrated into highly absorbent fibers with a pulp-like consistency." The physical changes suggest that crystalline regions in the cellulose have been opened up, giving easy access to enzymes.

An enzyme from the fungus, *Trichoderma,* converted more than 95 percent of the cellulose in the straw to glucose. It converted less than 20 percent of the cellulose in untreated straw to glucose.

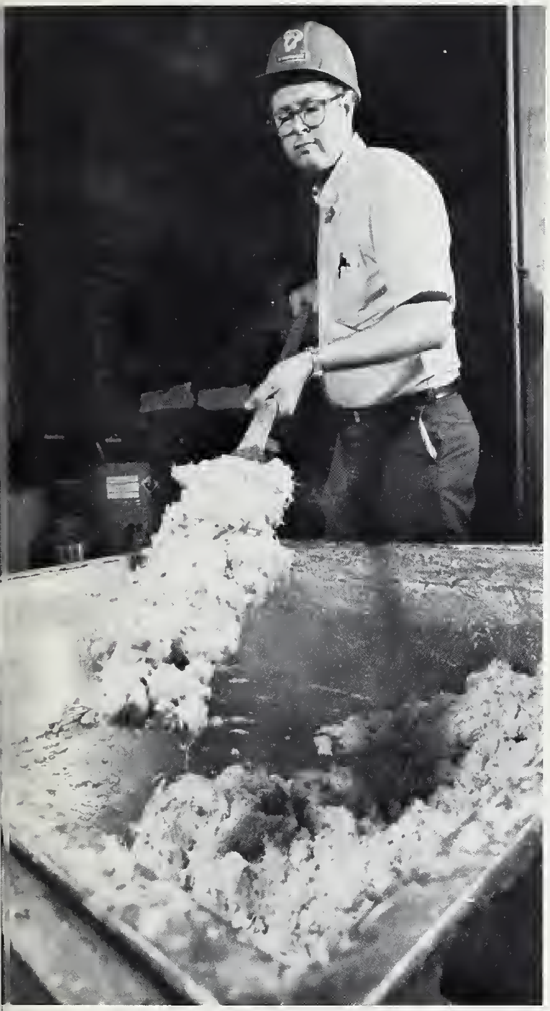
A yeast, *Saccharomyces,* converted glucose to ethyl alcohol, yielding about 90 percent of all the alcohol that the straw cellulose could produce. Another yeast, *Pachysolen,* can convert xylose, a sugar in hemicellulose, to alcohol in a process developed at the NRRC (see *Agricultural Research,* July-Aug. 1982, p. 8).

The treatment uses 1 part peroxide to 4 parts chopped straw, a proportion that might be too costly in an industrial scale process, depending upon the value of the feed and industrial products. "Complete use of the cellulose, hemicellulose, and lignin from agricultural residues to produce cattle feed, simple sugars, alcohol, and feedstock chemicals would be a positive factor in the overall economics of a commercial peroxide process," Gould says. "Furthermore, continuing studies on the lignin-degrading mechanism might result in the requirement of less peroxide."

A commercial process could aid soil conservation, he says. It could furnish a market for grass or other soil-protecting crops planted instead of row crops or cultivated crops on hillsides and strip-mined land.

Feeding studies have started in cooperation with George C. Fahey, Jr., animal scientist at the University of Illinois. Cattle appear to digest all of the treated straw, primarily cellulose, within 24 hours. They digest less than half of the untreated straw, even after 72 hours.

"Lignin products formed during the peroxide reaction include a significant



Top: Engineer Ron Montgomery shovels from a draining bin chopped straw treated with alkaline hydrogen peroxide. It will be used—after pressing, drying, and grinding—in a large-scale feed production pilot project. (0783X879-6)

Above: Feeding experiments also involve cows with fistulas through which treated straw can be removed for analysis after various periods of time in the rumen. (0783X866-9)

In ruminant feeding trials conducted in cooperation with the University of Illinois, Gould (left) and Illinois animal scientist George C. Fahey, Jr., encourage a lamb to try their new mixture of hydrogen-peroxide treated straw plus corn, molasses, and other ingredients. (0783X865-14).

proportion of low molecular weight carboxylic acids, which have potential as chemical feedstocks," Gould says. These products appear less toxic than the phenolic acids formed in other lignin-degrading treatments.

"Numerous pretreatments, many based upon pulping processes, have been developed to increase the susceptibility of cellulose in agricultural residues and wood to digestion by enzymes," Gould says. Most pretreatments have some major drawback. If they make all the cellulose available for digestion to glucose, they use too much fuel, use expensive or toxic chemicals, or generate toxic products.

Gould compared how the yeast, *Saccharomyces*, grew and produced alcohol on three different media—cellulose, one containing the dissolved lignin, and a conventional fermentation medium. "Neither the lignin-containing solution nor the treated cellulose appeared to be toxic or inhibitory to the yeast's growth or ethanol production," he says.

Isoluble material, mostly lignin, that remained after both peroxide treatment and digestion by the *Trichoderma* enzyme amounted to about 7 percent of the original straw. "In other words," Gould says, "93 percent of the wheat straw sample was solubilized by the combined treatment with alkaline peroxide and *Trichoderma* enzyme."

J. Michael Gould is located at the Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604.—(By Dean Mayberry, Peoria, Ill.) ■

Barley and triticale grown for forage or silage. Beans were planted as a second crop. (0782X772-25)

As the leaf ages, its palatability to livestock doesn't change much, but as the stem ages its palatability lessens dramatically because of the lignin it accumulates.

Lignin is in itself indigestible, but it also ties up the cellulose and hemicellulose in the stem. This means that the accumulation of lignin is the primary cause of the overall loss of quality as the plant matures, even though grain is accumulating at the same time.

That statement emphasizes the importance of the early harvest of barley as a forage crop shown in studies by ARS agronomist Gordon C. Marten, who is collaborating with University of Minnesota ruminant nutritionist R. M. Jordan.

In what amounts to mission-oriented basic research, the scientists are literally taking plants apart nutritionally and agronomically to find out which can serve the most practical and effective roles in farming systems as feed for cattle and sheep. In the process, they keep needs of livestock producers, particularly production efficiencies, foremost in their minds.

How much of the digestible nutrients is available in barley and other annual forages? How do they compare with top grade alfalfa? Can we develop a double-cropping system that will also meet emergency feed needs? Can barley be planted and harvested early enough to allow for a second forage? Will barley be suitable as a companion crop in establishing alfalfa?

Not all answers are in; some are, including comparisons of yields and quality of small grain crops grown and harvested as forages.

Assisted by graduate student J. H. Cherney, Marten reports they found that barley usually yields more forage dry matter, digestible dry matter, and crude protein than do oats, wheat, or triticale. This led to a close examination of barley as a first crop in a double-cropping annual system. It also led to a study, now in progress, to determine how barley compares to oats as a good companion crop.

In double cropping for forage, Marten says, barley must be planted as early as possible in the spring and harvested for silage at least by June 20 under Minnesota conditions. At harvest, barley will be in the boot or early-heading stage, depending on the year. A second crop is then planted immediately.

Besides Sudangrass and annual ryegrass, Marten and Jordan are studying soybeans, cowpeas, turnips, forage rape, and the common weed kochia (*Kochia scoparia*) as potential second crops for grazing in August through or into October.

Marten equates the feed value of barley silage harvested at the boot stage with that of top-grade alfalfa, whereas that harvested at the dough stage is considerably lower—equal to third- or fourth-grade alfalfa. This quality loss is caused by increased lignification of stem tissue between boot-to-dough stage.

The yearly harvest of a small-grain crop as silage also greatly reduces the risk of crop loss because of wind, rain, and hail, he says, and enables livestock producers to more fully utilize labor, equipment, and storage before harvesting corn as silage later in the season.

Gordon C. Marten is located in Rm. 404, Agronomy Bldg., University of Minnesota, St. Paul, Minn. 55108—(By Robert E. Enlow, Peoria, Ill.) ■

Soil Acidity and Drought Spell Trouble

Acidic soils cause double-trouble for sunflowers and other crops suffering from water shortages, according to ARS plant physiologist Donald T. Krizek.

In acidic soils, aluminum can easily dissolve and cause a stunting of the roots of sensitive plants. These deformed roots, which are inefficient in absorbing water and nutrients, result from a condition commonly called "aluminum toxicity."

"Adding lime can neutralize acidic soils and compensate for some of the damage caused by drought," says Krizek. "Similarly, additional water can minimize the damage caused by aluminum toxicity."

In experiments at the Beltsville Agricultural Research Center, sunflowers were subjected to both water stress and aluminum toxicity. Their growth was reduced about 70 percent by the combined stresses, according to Krizek, who cooperated with soil scientist Charles D. Foy. In acidic (pH 4.5) soil, growth was reduced by about 40 percent, even though the plants had enough moisture.

Some plants thrive in acidic soils, but other important crops—such as wheat, oats, soybeans, barley, sorghum, alfalfa—are sensitive to the aluminum toxicity that is common in many acidic soils.

Some varieties of sunflowers are more sensitive to aluminum toxicity and to drought than others. "We are looking for measurable differences between varieties that tolerate water stress and aluminum stress and those that do not," says Krizek. Such information would be used for screening germplasm to find the most stress-tolerant varieties.

Aluminum-toxic soils occur in the Eastern United States, especially the Southeast, and other parts of the world that have high rainfall. Current use of nitrogen fertilizers—mainly ammonium sulfate and ammonium nitrate—increases the aluminum toxicity problem in our soils, says Foy.

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Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.—(By Ellen Mika, Beltsville, Md.) ■

Hot Winds Damage Winter Wheat

Just one day of hot, dry winds can reduce winter wheat yields by 30 percent if the winds occur while the plants are in the milk stage. Wheat plants in the flowering stage or soft dough stage also suffer from hot winds and subsequent yields can be reduced by 25 percent.

"Most of the yield reduction, 80 percent, was a result of the first 2 to 4 hours' exposure to the winds. These winds did not reduce yields when they occurred before the flowering stage or after the soft dough stage," says ARS soil scientist Darryl E. Smika.

Smika, with soil scientist R. Wayne Shawcroft, formerly with ARS, measured hot wind damage so that economic planners could better predict domestic and worldwide wheat supplies. The data will also enable researchers to recalculate after harvest the effects of various experimental treatments on plots hit by hot, drying winds.

The scientists used a portable wind tunnel to subject wheat plants to either 20- or 40-mile-per-hour winds that were 10°F warmer than the surrounding air. Both windspeeds damaged crop yields equally.

"The winds we applied to the test plots were comparable to weather conditions we experience about 1 out of every 8 years here in eastern Colorado. Other areas of the Central and Southern Great Plains probably have damaging hot winds more often because of their geographical landscape. Also, large areas in other parts of the world, especially the Soviet Union, are vulnerable to wind damage," says Shawcroft.

Hot winds during the flowering stage reduced yields primarily by causing more wheat heads to fail to produce any grain. During the milk stage, most of the resulting yield reduction was because fewer kernels per head developed. During the soft dough stage, hot winds reduced yields by reducing the weight per kernel.

This research was partially funded by the National Aeronautics and Space Administration and USDA's Economic Research Service.

Darryl E. Smika and R. Wayne Shawcroft are located at the Central Great Plains Research Station, P.O. Box K, Akron, Colo. 80720.—(By Dennis Senft, Oakland, Calif.) ■

Mothers' Milk Goes Further

Breast-fed infants attain growth rates comparable to formula-fed infants, although they consume less protein and energy, according to Nancy F. Butte, a researcher with the Children's Nutrition Research Center in Houston, Tex., which is funded by ARS.

"Despite lower energy and protein intake after the first month of life, breast-fed infants gain weight at rates similar to formula-fed infants. In fact, the ratios of weight gain to caloric intake indicate a more efficient use of protein and energy among breast-fed infants for growth."

The research results document human milk intake and growth performance of 45 exclusively breast-fed infants during the first 4 months of life. By 4 months of age, the breast-fed infants consumed about 25 percent fewer calories than formula-fed babies. Similarly, the protein intakes of breast-fed infants were appreciably less than those of formula-fed babies, even though the protein-to-calorie ratio of commercially available formulas has been adjusted to approximate human milk.

A young mother nurses her baby under the supervision of Carolyn Heinz, a research assistant at the Children's Nutrition Research Center. (0982X1128-29)

Butte worked on the 4-month study with assistant professors Cutberto Garza and E. O'Brian Smith, and in collaboration with professor Buford L. Nichols, the center's scientific director.

Nancy F. Butte is located at the Children's Nutrition Research Center, 6608 Fannin, Suite 601, Houston, Tex. 77030.—(By Neal Duncan, New Orleans, La.) ■

Bean Sprouts Need Cold Temperatures

Salability of mung bean sprouts, available in most supermarkets and many restaurants in this country and a dietary staple in the Far East, can be prolonged with careful management of temperature from their harvest until they are displayed on counters.

Plant pathologist Werner J. Lipton, Fresno, Calif., found that bean sprouts were judged to be in salable condition up about 8-1/2 days when they were kept at near freezing—32°F.

At higher temperatures—36°, 41°, and 50°F—the sprouts become unsalable in 5-1/2, 4-1/2, and 2-1/2 days, respectively.

Lipton says that is is difficult for retail outlets to keep refrigerated food sections at 32°F, but if growers

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promptly precooled the sprouts to near 32°F and if transporters, wholesalers, and retailers held them as close to that temperature as possible, they would help to maximize the shelf life of the sprouts.

Major symptoms of deterioration are a darkening of the sprouts, development of sliminess, decay and musty odors, and increased streaking of hypocotyls. In fresh sprouts the hypocotyls—main portion of sprout—are white. Upon aging, they darken to a light buff and eventually to beige and light tan. This darkening became perceptible when sprouts were held 6 to 7 days at 32°F, but appeared much sooner at higher temperatures. Upon transfer of sprouts to 50°F, which simulates store counter temperatures, the hypocotyls remained white for 2 or 3 days when they were previously stored at 32°F and for 2 days if they had been stored at 36° or 41°F.

Nearly 25 million pounds of sprouts are grown in this country each year, with most of them grown close to the market area being served.

A full report on this research is available from Werner J. Lipton at the ARS Market Quality and Transportation Unit, U.S. Horticultural Field Station, P.O. Box 814, Fresno, Calif. 93727.—(*By Paul Dean, Oakland, Calif.*) ■

Simple Lab Techniques for Plant Pathologists

It is amazing what one can do with cyanoacrylic adhesives—better known by such trade names as Superdrop and Superglue. Plant pathologists Charles L. Wilson and P. Lawrence Pusey have found they can section and permanently mount plant tissue with a dab of the sticky stuff. The scientists simply apply a little glue to a leaf's outer surface or a freshly cut inner surface, press it against a slide until the glue sets (at least 3 minutes), then peel away the unglued portion. What is left is a thin layer of unperturbed tissue in a clear, permanent mount that lasts for several months.

The technique is inexpensive and simple; permanent mounts can be made right in the field for diagnosing diseases. And they show excellent detail without a cover slip under either the dry or oil-immersion objectives of a light microscope.

Wilson says he borrowed the idea from dermatologists who use "glue slides" to diagnose skin problems. He expects the technique will be valuable for studying the penetration and growth of plant pathogens as well as for diagnosing diseases.

Pusey hit upon another technique while working with research horticulturist Ralph Scorza. The two scientists found that multiwell plates used in serological tests are excellent for studying the effects of plant extracts, fungicides, or other chemicals on the germination of fungal spores. The clear polystyrene plates, which contain 96 flat-bottom wells each, make it easy to vary and replicate such evaluations because they require so little space and test material.

The multiwell plates are also ideal for measuring the amount of germination. Special dyes can be added to the wells and the color intensity read by eye or by spectrophotometer.

Charles L. Wilson and Ralph Scorza are located at the Appalachian Fruit Research Station, Rt. 2, Box 45, Kearneysville, W. Va. 25430. P. Lawrence Pusey formerly at Kearneysville, is now located at the Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, Ga. 31008.—(By Judy McBride, Beltsville, Md.) ■